Habitat Suitability Analysis for Big-Headed Turtles (*Platysternon megacephalum*) in Ban Huak Forest, Phayao, Thailand

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Abstract

This research aimed to investigate the demographic characteristics and analyze the suitable habitats for Big-Headed Turtles in the Ban Huak forest area, Phu Sang Subdistrict, Phu Sang District, Phayao Province. The research methodology consisted of surveying and collecting data on Big-Headed Turtles from 51 ranges of sample streams, each 100 meters long, an analysis of information on the density and frequency of Big-Headed Turtles distribution, and an analysis of suitable habitats by applying Geographic Information System (GIS) Overlay Function combined with logistic regression equations to identify areas with a probability of 50% or higher for Big-Headed Turtles presence, indicating suitable habitats. The study found that the density of Big-Headed Turtles in the study area was 3.18 per kilometer, and the distribution frequency along the sample streams was relatively low (30.30%). The habitat suitability analysis using Logistic Regression Analysis identified that six predictive variables affecting the sighting of Big-Headed Turtles included forest type, stream order, slope, elevation, distance from community, and distance from forest protection unit with statistical significance at the 0.05 level. A Binary Logistic Regression equation was developed to analyze suitable habitats for the presence of Big-Headed Turtles with a prediction reliability of 88.24%. Suitable habitats with a 50% or higher probability of Big-Headed Turtles presence were located in the northern and northeastern parts of the study area.

Keywords: Big-Headed Turtles, Demographic Characteristics, Habitat Suitability, Phayao

1. Introduction

The Big-Headed Turtle is a rare reptile species in Thailand, classified as endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (2007) and listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It is also protected under the Wildlife Preservation and Protection Act, B.E. 2546 (2nd Edition). These turtles are found in southern China, Myanmar, Thailand, Laos, Cambodia, and northern Vietnam. The first sighting in Thailand was reported in 1915 in Mae Hong Son, Phetchabun, Chaiyaphum, and Kanchanaburi. Recent surveys indicate that Big-Headed Turtles are distributed across 10 major watersheds in northern, northeastern, central, and western Thailand, primarily at 430-1,350 meters above sea level. They predominantly inhabit small, fast-flowing streams in dry evergreen and hill evergreen forests [1] and [2].

At present, the population of Big-Headed Turtles has rapidly declined due to deforestation, which affects their living areas, breeding grounds, and food sources, as well as hunting for consumption and sale. The breeding is still not possible as they do not lay eggs in artificial ponds because they inhabit only clean water in flowing streams, particularly in forest area like Ban Huak, a border village between Thailand and Laos, which is the only area in Phayao Province where Big-Headed Turtles have been found.

Currently, it's found that there are people from neighboring countries who come to purchase Big-Headed Turtles and deliver to consumers who like to consume rare animals in China and Vietnam. These consumers believe that these rare animals are sexual tonics, leading to high prices ranging from 4,000 to 10,000 baht per kilogram [3] and [4]. From this belief, this animal has become a rare commodity in neighboring countries due to its decreasing number. Therefore, people are illegally entering the area of Phu Sang District, Phayao Province on a regular basis.

One of the conservation and restoration strategies for endangered or threatened rare species if considering the policies on conservation and sustainable use of biodiversity, aims to enrich biodiversity, reduce the rate of biodiversity loss, and maintain ecosystems, species, and important genetic sources and protect relevant biodiversity components of the country, it is obvious that before implementing conservation and restoration management for any rare wildlife species, it is essential to understand the nature of the species, including its biology, ecology, habitat, and any normal or abnormal aspects related to it. These crucial data, currently, can be applied using geo-information technology as a tool for surveying, monitoring, collecting, analyzing, and displaying wildlife data in the form of density maps and distribution patterns. Furthermore, it can analyze suitable habitats based on various environmental factors related to the wildlife's livelihood, combined with statistical methods such as Logistic Regression Analysis [5][6][7][8] and [9]. This analysis helps predict the probability of encountering or presence of rare wildlife under different environmental conditions [10] and [11]. This information is very important for making decisions on conservation strategies for rare and endangered wildlife in various areas effectively and appropriately [12] and [13].

Given the reasons mentioned above, the researcher is interested in exploring the demographic characteristics and analyzing the suitable habitats for Big-Headed Turtles in the Ban Huak forest area, Phu Sang Subdistrict, Phu Sang District, Phayao Province. This is the only area in Phayao Province where this turtle species has been found, and there have been no previous surveys or studies on Big-Headed Turtles in Thailand. Additionally, this area faces high risks of threats and extinction due to poaching for sale by neighboring countries, as it is a forested border area that is difficult to control. This study will apply geo-information technology to assist in surveying, collecting, analyzing, and displaying data. Moreover, it will use statistical analysis methods such as Logistic Regression Analysis to analyze suitable habitats based on factors influencing wildlife habitat selection, including physical factors, biological factors, and human activity impacts. This information will aid in making decisions for monitoring, establishing protective boundaries, and conserving Big-Headed Turtles in the study area.

2. Research Objective

The objective of this study is to explore the demographic characteristics and analyze the suitable habitats for Big-Headed Turtles in the Ban Huak forest area, Phu Sang Subdistrict, Phu Sang District, Phayao Province. The study aims to utilize geo-information technology and statistical analysis to identify factors influencing habitat selection and to provide data that will support conservation efforts, including monitoring, establishing protective boundaries, and mitigating threats from poaching.

3. Study Area

The study area is the forest of Ban Huak, located in Phu Sang Subdistrict, Phu Sang District, in the northeastern part of Phayao Province, in the upper northern region of Thailand, bordering the Lao People's Democratic Republic. The geography of the area is characterized by alternating plains and mountains [14] and [15], with more than 60% of the area being mountainous and forested. This area is rich in biodiversity, both in terms of flora and fauna, making it one of Thailand's ecologically significant regions (Figure 1). The forest of Ban Huak is part of a larger ecosystem that includes a variety of habitats such as dry evergreen forests, hill evergreen forests, and mixed deciduous forests. These diverse habitats support a wide range of wildlife, including several endangered and endemic species. The area is also home to numerous streams and rivers, which are crucial for maintaining the ecological balance and providing water resources for both wildlife and local communities.

4. Research Methodology

4.1 Surveying Data of Big-Headed Turtles

4.1.1 Selection of streams

The selection process involved identifying streams or creeks considered as habitats for Big-Headed Turtles within the study area that was achieved through group meetings and consultations with local residents, resulting in the identification of four routes (Figure 2). The starting and ending points of each stream were determined, and the length of each stream was measured, along with the elevation above sea level. The streams were then divided into 100-meter ranges, resulting in a total of 51 survey ranges, covering a total survey distance of 5,040 meters (Table 1).

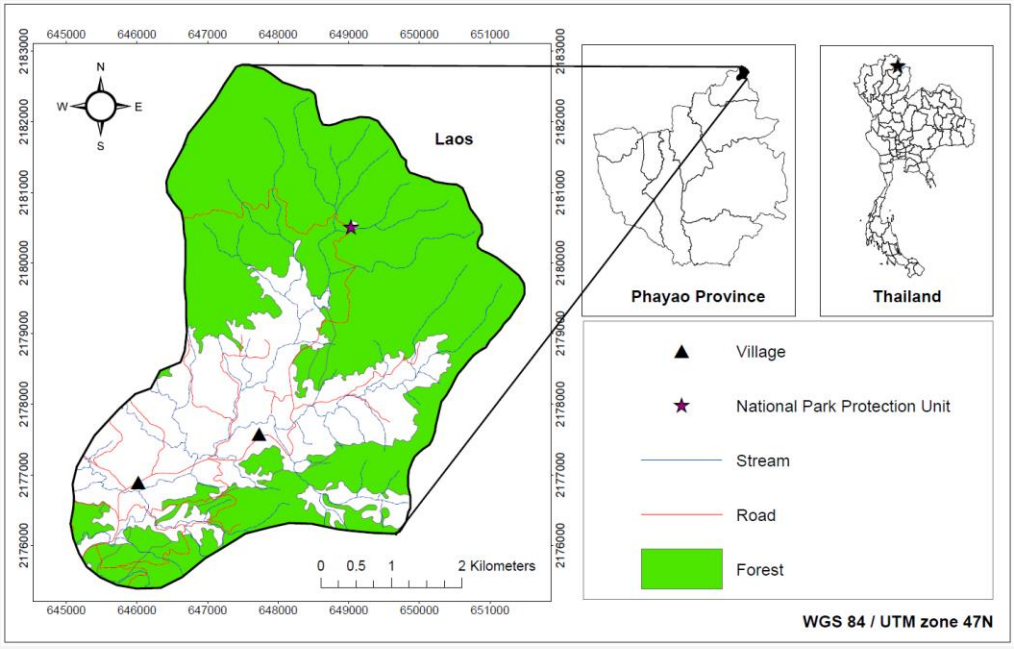

Figure 1: Ban Huak forest area, Phu Sang District, Phayao province

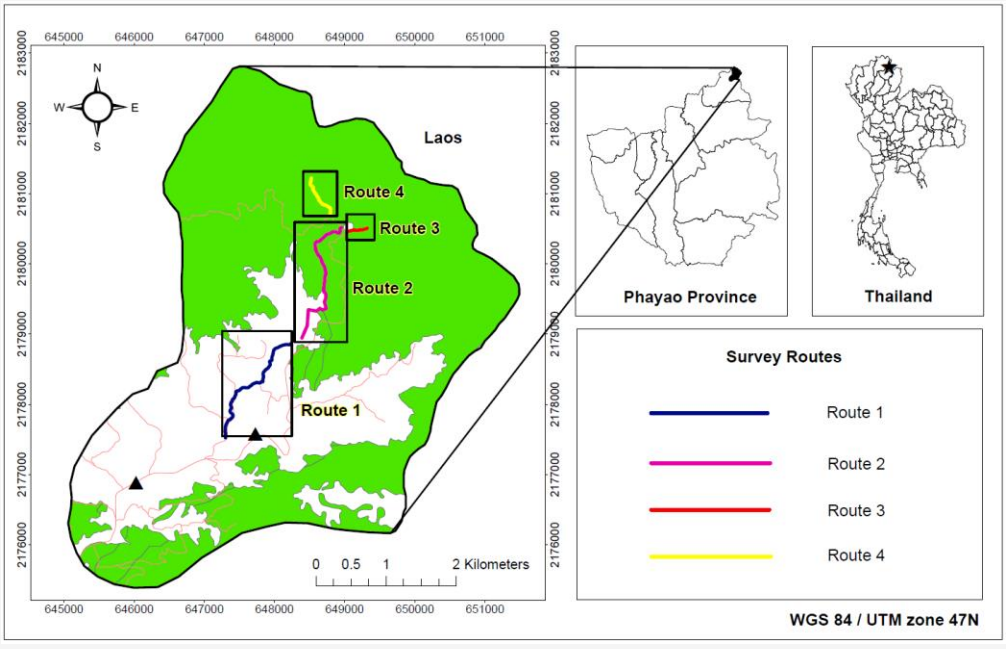

Figure 2: Survey routes of Big-Headed Turtles

Table 1: General characteristics of the survey area

Route	Distance (meters)	Number of ranges	Elevation above sea level (meters)	Area characteristics
1	1,899	19	500-520	Small rocks mixed with sand scattered throughout the stream; not very steep.
2	2,190	22	557-644	Small rocks scattered throughout the stream; increasingly steep with a lot of leaf litter.
3	294	3	640-739	Large rocks interspersed with small waterfalls.
4	657	7	654-726	Rocks scattered throughout the stream; not very steep.

According to [16], the streambed features a variety of sedimentary compositions and gradients (Table 1). The streambed is composed of small rocks mixed with sand, indicating a relatively low-energy environment where finer sediments can settle. The gradient here is gentle, suggesting minimal erosion and sediment transport. As the stream progresses, small rocks continue to dominate the substrate. The gradient becomes steeper, which increases the stream's energy and its ability to transport larger particles. The presence of significant leaf litter indicates a dense canopy cover, contributing organic material to the stream. Additionally, this study stated that large rocks are interspersed with small waterfalls, creating a more dynamic and erosive environment. The waterfalls indicate a sudden change in gradient, leading to increased water velocity and turbulence, which can erode and transport larger rocks. Overall, the stream exhibits a transition from a low-energy, depositional environment to a high energy, erosive environment, and back to a more stable, depositional setting. This variation in geological features reflects the dynamic processes shaping the stream's morphology and sediment distribution

4.1.2 Surveying and collecting data on Big-Headed Turtles in each stream

Data collection was conducted through direct observation by sighting the turtles. Daytime surveys were carried out using methods such as searching under rocks, in rock crevices, and various pools along the entire length of the streams. The survey was conducted during the low rainfall period in December 2016. Each turtle found was marked, recorded, and then released at the same spot. Environmental and turtle data collected included species, sex, weight, range of the stream where found, and site characteristics (e.g., water basins, rock crevices, and characteristics of water basins) [17][18][19] and [20].

4.1.3 Analyzing the density and distribution frequency of Big-Headed Turtles in the study area included

4.1.3.1 Demographic density analysis

The density of Big-Headed Turtles in the area was analyzed by calculating a number of Big-Headed Turtles found per unit distance surveyed [21]. The density could be calculated using the Equation 1.

$$D = \frac{TB}{S}$$

Equation 1

Where: D is the density of Big-headed turtle, TB is the number of Big-headed turtles found, and S is the surveying distances

4.1.3.2 Distribution frequency analysis

The distribution frequency was analyzed by calculating the percentage frequency of Big-Headed Turtles found in each range of the stream surveyed. The distribution frequency is defined in Equation 2 [22].

$$D_f = \frac{TR}{TS} \times 100$$

Equation 2

Where: D_f is the distribution density of Big-Headed turtle, TR is the total number of ranges where Big-headed turtle were found, and TS is S is the surveying distances

The results were interpreted as the overall probability of encountering Big-Headed Turtles in the study area, categorized into five groups: Rare (0-20%), Uncommon (21-40%), Common (41-60%), Very Common (61-80%), and Abundant (81-100%).

4.2 Suitable Habitat Analysis

The suitable habitat analysis considered three main factors: 1) Biological factors **(**forest type) 2) Physical factors (stream order, slope, and elevation above sea level) and 3) Human impact factors **(**distance from community, distance from roads, and distance from forest protection unit) (Table 2) by considering the surveyed locations where Big-Headed Turtles were found [11] and [12]. Then the frequencies were distributed by considering the importance of factors with higher frequencies by using the overlay technique of the Geographic Information System together with the use of statistical method, Logistic Regression Analysis to analyze habitats suitable for appearance in the form of a Binary Logistic Regression equation as follows. These factors were assessed based on the locations where Big-Headed Turtles were found and the frequency distribution of these factors, emphasizing those with higher frequencies. The overlay technique of Geographic Information System (GIS) was used in combination with statistical methods, specifically Logistic Regression Analysis, to analyze suitable habitats for Big-Headed Turtles. The analysis was formulated into a Binary Logistic Regression Equation [23] and [24] as expressed in Equations 3 and 4:

$$Prob(event) = \frac{e^z}{1+e^z}$$

Equation 3

Where:

e is the Euler's number.

Z is the linear combination defined in Equation 4.

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i$$

Equation 4

Where:

Prob(event) is the probability of encountering Big-Headed Turtles, the value ranges between 0 and 1.

$\beta_0, \beta_1, \beta_2, \ldots \beta_i$ are the logistic regression coefficients.

$X_0, X_1, X_2, \ldots X_i$ are the predictive variables used in the research.

Whereas *Prob(event)* $\geq$ 0.5 it indicates a high probability of encountering Big-Headed Turtles in that area [25].

5. Results

5.1 Survey of Big-Headed Turtles

The survey results indicated that a total of 10 Big-Headed Turtles (Table 3) were found over six surveys within one month. The species identified was the Siamese Big-headed Turtle (*P.m.peguense*) (Figure 3). The distinguishing features of this species included a dark brown carapace, head, and tail, five pairs of scales on the spine, eleven pairs of scales on the edge of the shell, one pair of scale above the nape, and three pairs of scales above the base of the tail [25] and [26]. These turtles were found distributed along streams at elevations of approximately 560 to 728 meters above sea level (Figure 4). The surrounding environment of the streams where the turtles were found was characterized as mixed deciduous forest. The streams contained both small and large stones, clear flowing water resembling small waterfalls, and maintained water flow throughout the year. The streambeds were composed of gravel, sand, and a significant number of decomposed leaves along the entire stream. In addition, along the study route, a variety of other animals were also observed, such as leaf turtles, long-legged spiders, shrimp, crabs, cabbage worm butterflies, etc. The highest number of Big-Headed Turtles was found along route 2, with 5 turtles. This was followed by routes 4 and 3, with 3 turtles and 2 turtles respectively. When considering the demographic density and frequency of distribution, route 2 had the highest demographic density and frequency of distribution, with 6.80 turtles per kilometer and a distribution frequency of 66.6%. This was followed by route 3 (4.57 individuals per kilometer and a distribution frequency of 42.85%) and route 1 (2.28 turtles per kilometer and a distribution frequency of 22.72%), respectively (Table 4).

Table 2: Predictive variables used in the research

Predictive variable	Parameter
Forest type (0: Not mixed deciduous forest, 1: Mixed deciduous forest)	X_1
Stream order (1, 2, 3 and 4)	X_2
Slope (%)	X_3
Elevation above sea level (meters)	X_4
Distance from community (meters)	X_5
Distance from roads (meters)	X_6
Conservation forest area (0: Not conservation forest, 1: Conservation forest)	X_7
Distance from forest protection unit (meters)	X_8

Table 3: Surveyed Big-Headed Turtles found

ID.	Route	Gender	Weight (kg)	Characteristics of the surveyed area
1	2	Male	0.50	under the rock
2	2	Male	0.65	in a puddle
3	2	Male	0.28	in a puddle
4	2	Female	0.58	under the leave
5	2	Male	0.83	in a puddle
6	3	Female	1.20	under the rock
7	3	Male	1.74	in a puddle
8	4	Female	2.04	in a puddle
9	4	Male	0.67	under the leave
10	4	Male	1.00	under the rock

Figure 3: Big-Headed Turtles found in field survey routes

Figure 4: Environmental characteristics of field survey routes

Table 4: Demographic density and distribution frequency

Route	A number of Big-Headed Turtles found (turtles)	A number of ranges found (ranges)	Population density (turtles/km)	Distribution frequency (%)
1	-	-	-	-
2	5	5	2.28	22.72
3	2	2	6.80	66.66
4	3	3	4.57	42.85
Total	**10**	**10**	**3.18**	**30.30**

5.2 Suitable Habitat Analysis

By analyzing the eight predictive variables using Logistic Regression Analysis and the Maximum Probability method to estimate parameter values (regression coefficients), it was found that six variables significantly influenced the presence of Big-Headed Turtles at a 0.05 significance level (Table 5). Base on the calculated coefficients, the logistic regression equation predicting the variables influencing the presence of Big-Headed Turtles can be Equations 5.

$$Z = -50.974 + 20.189(X_1) + 2.064(X_2) + 0.009(X_3) + 0.054(X_4) - 0.002(X_5) - 0.002(X_8)$$

Equation 5

Table 5 presents the results of the coefficient analysis of various variables, including the relevant statistics related to logistic regression analysis. This analysis aimed to predict which variables influence encountering of Big-Headed Turtles in the study area. The analysis showed that there were six variables affecting encountering of Big-Headed Turtles: forest type (X_1), stream order (X_2), slope (X_3), elevation above sea level (X_4), distance from the community (X_5), and distance from the forest protection unit (X_8). Base on the suitability inspection of the logistic regression equation by using the Hosmer and Lemeshow test method, it resulted in a Chi-square statistic of 2.237 and a P-value of 0.973. Since the P-value was greater than the statistical significance level of 0.05, we accepted the null hypothesis that the equation was suitable for the logistic regression analysis.

Table 5: Variables in the equation

Variables	B	S.E.	Wald	P-value
X_1	20.189	3.688	0.000*	0.034
X_2	2.064	1.527	1.724*	0.042
X_3	0.009	0.042	0.045*	0.012
X_4	0.054	0.043	1.603*	0.048
X_5	-0.002	0.005	0.194*	0.009
X_8	-0.002	0.003	0.295*	0.027
constant	-50.974	3.715	0.000*	0.000

* P-value < 0.05

Table 6: Reliability of the prediction

Observed		Predicted		
		Found or not found		Percentage correct
		Found	Not found	
Found or not found	**Not found**	38	3	92.68
	Found	3	7	70.00
			Overall percentage	**88.24**

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Table 6 demonstrates the reliability of the prediction. The survey consisted of 41 sample ranges where Big-Headed Turtles were not found. By incorporating variables into the equation, the prediction correctly identified 38 ranges where Big-Headed Turtles were not found, achieving a prediction accuracy of 92.68%. Among the 10 sample ranges where Big-Headed Turtles were found, the equation correctly predicted 7 ranges, resulting in a prediction accuracy of 70%. Overall, the average prediction accuracy was 88.24%. For analysis of suitable habitats for Big-Headed Turtles, the study applied a spatial data overlay method using six predictive variables (Figure 5) combined with logistic regression equation to identify areas with a high probability of encountering Big-Headed Turtles in the Ban Huak Forest, Phu Sang District, Phayao Province. Areas with a probability of encountering greater than or equal to 50% were considered suitable habitats with a significant chance of encountering Big-Headed Turtles within the study area. The findings indicated that suitable habitats were located around streams in the Ban Huak Forest, particularly in the northern and northeastern parts of the study area, covering approximately 1.41 square kilometers. These habitats could be further classified based on the probability of turtle presence: areas with a 50% – 75% probability cover approximately 0.17 square kilometers, while areas with the highest suitability, with a probability of more than 75%, cover approximately 1.24 square kilometers (Figure 6).

6. Discussion

The Big-Headed Turtles surveyed in Ban Huak Forest, Phu Sang District, Phayao Province, belonged to the subspecies called the Siamese Big-headed Turtle (*P.m.peguense*). These turtles were primarily found in burrows or under rock crevices, especially in areas with waterfalls or fast-flowing streams [13]. Local villagers in Ban Huak often observed juvenile turtles (small-sized) being washed down the streams during the rainy season. They were typically found near an area where the remains of shellfish or crabs that were eaten and left on rocks in the creek appeared. In this study, the smallest Big-Headed Turtle weighed approximately 28 grams, while the largest weighed 2,400 grams. The Big-Headed Turtles in study area were distributed in areas with elevation ranging from 600 to 720 meters above sea level, living in streams that flow year-round. They tended to hide under rock crevices, particularly in fast-flowing waterfalls.

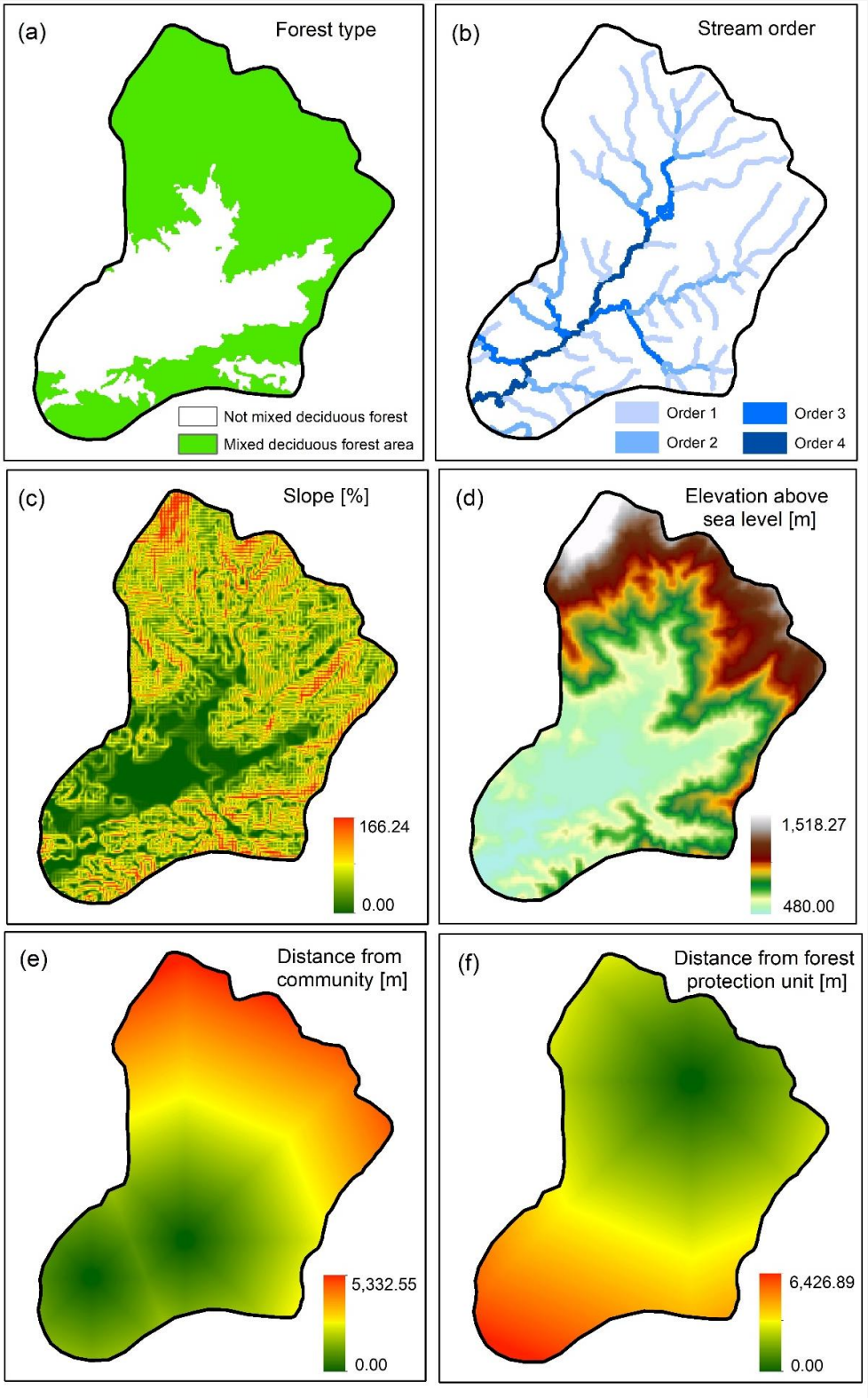

Figure 5: Spatial predictive variables for the probability of encountering Big-Headed Turtles: (a) Forest type (b) Stream order (c) Slope (d) Elevation above sea level (e) Distance from community and (f) Distance from forest protection unit

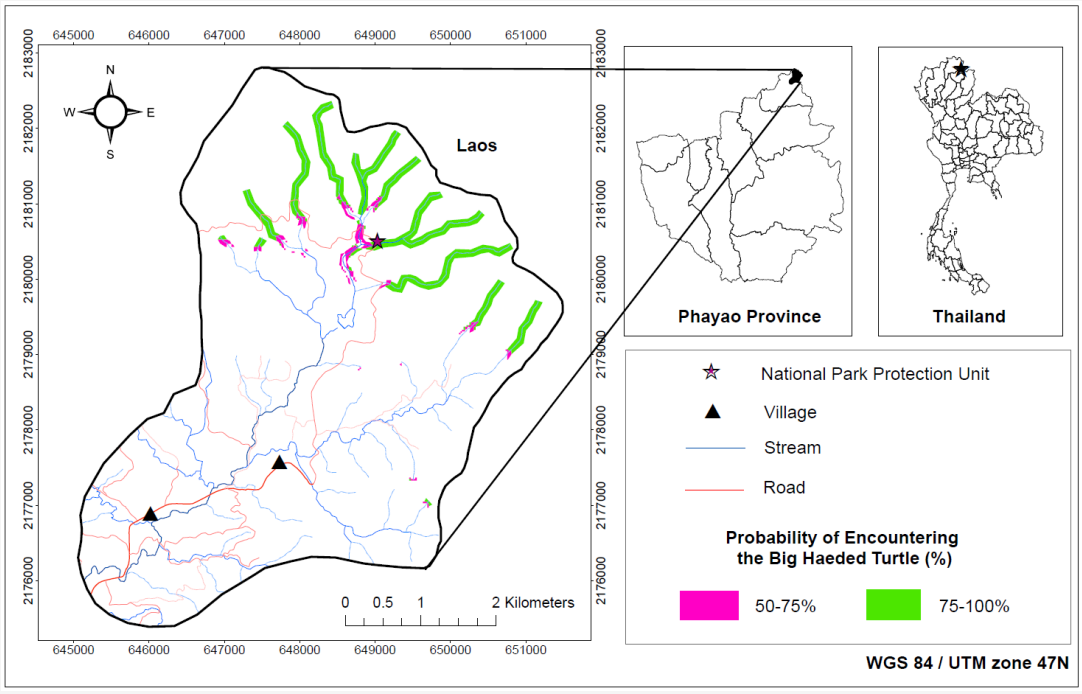

Figure 6: Suitable habitats with high probability of encountering Big-Headed Turtles

Juvenile turtles were found in areas with less steep slopes, likely because they could be easily washed away by water. Medium and large-sized turtles inhabited steeper areas with stronger water flow [1][25] and [26]. The density and frequency of distribution of Big-Headed Turtles in the study area were highest along the second survey route (Nam Puea-Huai Miang), while no turtle was found along the first survey route (Lower Nam Puea). This absence was likely due to the survey period being during the dry season, as juvenile turtles were typically washed down during the rainy season with heavy rainfall and strong water flow.

Considering the results of significant predictive variables for distribution of Big-Headed Turtles during the survey period, six variables were identified: forest type, stream order, slope, elevation, distance from the community, and distance from the forest protection unit. A logistic regression equation was developed, achieving a prediction reliability of 84.24%, using geographic information system (GIS) techniques to illustrate areas with a high probability of encountering Big-Headed Turtles. Areas with a probability greater than 50% were considered suitable habitats [25]. The verification experiment involved overlaying the observed positions of the Big-Headed Turtles with the habitat suitability map generated by the logistic regression equation. The results indicated an accuracy of approximately 70% during the survey period because this study was surveyed during the dry season when there was little water. To enhance the model's accuracy, it's recommended to collect data across all seasons and over multiple years. This comprehensive data collection would help to better understand the trends and clear relationships between independent and dependent variables, thereby improving the accuracy and precision of the predictive model. Moreover, the model's accuracy should be regularly tested against real-world data by incorporating new survey data. This continuous refinement would ensure that the model remained well-suited to the specific area and the prevailing conditions at any given time, resulting in the most accurate logistic regression equations for predicting turtle habitat suitability.

Finally, there should be a test of accuracy in real areas by using new survey data to constantly improve the model or equation to get the best variable equation to make it appropriate for the area and that time period [10][11][12] and [27].

7. Conclusion

The analysis of suitable habitats for the Big-Headed Turtle through the application of Geographic Information System (GIS) methods combined with logistic regression can identify areas with a high likelihood of species occurrence. This approach helps determine the probability and distribution of the species, indicating areas where they are most likely to inhabit. Additionally, it provides insights into key environmental factors influencing the habitat selection of the Big-Headed Turtle, which will be

beneficial for future habitat management and conservation efforts. Due to Big-Headed Turtles being a rare and endangered species with a relatively small population, the study found that their population density was quite low. Additionally, the local community lacked a deep understanding of the importance of wildlife conservation. The data from this study could be used to inform decision-making and develop strategies for conserving Big-Headed Turtles in the area. These strategies may include designating conservation boundaries, establishing wildlife sanctuaries, or creating breeding and research centers for the turtles.

Acknowledgements
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